NASA Administrator

Daniel S. Goldin

address as prepared for delivery

to the

American Geophysical Union

December 6, 1998

A View, A Vision, An Imperative

It is a great time at NASA.

It's our 40th anniversary and we're still basking in the glow of John Glenn's return to space and the success of STS-95.

As we speak, the astronauts aboard the Space Shuttle Endeavour are preparing for the historic space walks they will conduct while connecting the first two pieces of the International Space Station.

On December 10th, we launch the Mars Climate Orbiter, our third mission to the Red Planet in as many years.

We are also approaching another anniversary. Later this month marks the 30th anniversary of Apollo 8 . . . our first human lunar orbit mission.

While noting this last milestone might seem a bit esoteric to some . . . the images that came out of that mission certainly are not.

In fact, I wouldn't be surprised if "Earthrise" -- that awe-inspiring picture of the Earth appearing past the Moon's horizon -- was what inspired some of you to embark in the fields that are now your life's work.

That picture and others like it really go to why I am here . . . why NASA does what it does.

Simply put . . . NASA got into the Earth science business because we could bring something unique to the table: the ability to obtain the global <u>view</u> from space.

NASA could provide data on a broad range of spatial, temporal and spectral scales . . . so we launched the first weather satellites (TIROS) . . . then the first land surface imager (Landsat) . . . the first ozone monitor (TOMS) . . . and made the first satellite-based estimates of the Earth's radiation budget (ERBE).

We were on our way.

The view . . . led to a vision -- the vision that it is possible to understand the Earth as an integrated system of land, oceans, ice, atmosphere and life. And so NASA, with the help of you and other scientists around the world, pioneered the interdisciplinary field of Earth System Science.

We wanted to study the key spheres of interactions among these five Earth system components, so we launched a series of satellites over the past decade.

We've studied the upper atmosphere (UARS) . . . and ocean circulation (TOPEX/Poseidon) . . . and ocean color (SeaWiFS) . . . and the physics of the atmosphere (TRMM).

And soon we will launch the first Earth Observing System (EOS) missions to begin an era of long term, synoptic measurements of the most important Earth system interactions, such as the atmosphere-biosphere and atmosphere-oceans.

With your help and dedication, we are getting some outstanding science results from these missions.

We have an estimate of the radiation budget of the Earth, though it needs improvement.

We are monitoring total ozone concentrations and its annual cycle of polar ozone depletion and replenishment, and now understand the chemistry of human activities in that cycle.

And, one of the biggest accomplishments of recent years . . . we have a handle on the mechanics of the El Niño / La Niña a phenomenon, and we can observe its waxing and waning. Again, more work is required before we have a reliable prediction capability . . . but we are making incredible progress.

A sign of that progress is this: On behalf of scientists at the Center for Space Research at the University of Texas at Austin, led by Dr. Steven Nerem . . . and on behalf of the entire NASA Team . . .

I am proud to announce . . . that thanks to data supplied by TOPEX/Poseidon . . . we now believe that the 1997-1998 El Niño may have been a major factor in the global sea level rising almost a full inch -- eight-tenths of an inch -- before returning to its normal levels.

These kind of findings are the very important first steps in understanding the variations caused by climate change . . . and I congratulate the scientists who have worked so hard.

Clearly, these and all of the other science results have the potential for tremendous benefit to society. That is why the view became a vision . . . and the vision is now an imperative.

Earth science from space is not a curiosity or a luxury or a pastime -- it is a job that has to be done. Governments, industries and citizens need the information that Earth scientists provide.

And if we in the Earth science community are not thoughtful and deliberate in our actions . . . the world's need for answers will grow faster than our ability to provide them. The issues and needs are here today; the slower we go in understanding mechanics of global change, the larger will be the ecological and economic impacts of our actions.

At NASA and in the scientific community, our job is to provide the hard, objective information needed by the policy makers and industry to structure sound solutions.

So tonight, I want to talk about where we are and where we need to be going in this enterprise we call Earth system science. And I'll address this in three elements: science, technology, and operational systems.

Formulating Science Questions that Address Society's Needs

At NASA, we are extremely proud . . . not only because so many of the Earth science accomplishments were fed by data from NASA satellites and NASA-sponsored research programs . . . but also because we feel we have played an important role in getting traditional and stovepiped science disciplines to work together on interdisciplinary problems.

We are even seeing Earth System Science curricula emerging at the middle school, high school, and undergraduate levels.

But we have discovered that this interdisciplinary environment is not yet self-sustaining–not yet internalized by the science community. That is a challenge for AGU. That is a challenges for all of us.

On the content of the scientific inquiry itself, we are in the midst of a sea change in how we think of what must be done. For the past ten years, culminating in the EOS missions soon to be launched, we have been looking through a wide-angle lens to get the big picture of the Earth system and the basic mechanics of its large-scale processes.

These are just the first steps; we plan to do more in the future. We have started by studying global scale phenomena such as ozone concentrations.

We have moved to address regional scale issues, such as floods and tropical deforestation. And we are developing the capability to help with local scale concerns such as suburban land use planning.

But again, we need to do more. Both the growth in our understanding and the needs of economic & policy decision-makers are leading to the formulation of more pointed questions:

First -- the big one . . . Is climate changing in ways we can understand and predict?

To answer this, we need to be able to uncover the basic mechanics of climate, and then distinguish natural from human-induced impacts on the climate system.

Then we can build more accurate models of ocean-atmosphere interactions . . . of cloud formation and radiative balance . . . of chemical transport from land to atmosphere.

We need to fill in the blanks and reduce the uncertainties in our pictures of the global carbon cycle . . . the global water cycle . . . and the global energy cycle. Coupling these models together, we can begin to make useful predictions of temperature and precipitation patterns.

So NASA is developing lidars and radars to reveal the 3-D structure of the atmosphere and measure winds in the troposphere -- which would be a major step forward in weather prediction.

These steps enable us continue to provide ever stronger peer-reviewed science to policy makers. That way, our society can take appropriate steps to mitigate the human induced impacts of climate variations and extreme weather events, such as floods and droughts, on agriculture and commerce in a responsible manner. Reliable extended weather predictions will further minimize the economic impacts of these events.

Another question -- Can we understand and predict how terrestrial and marine ecosystems are changing?

Here, again, we need to be able to distinguish natural from human-induced changes in biodiversity and other ecosystem characteristics. Uncertainties in sources and sinks in the carbon and nitrogen cycles must be reduced . . . in some cases the uncertainties are greater than the current estimates! We need to understand how variability in temperature and precipitation induces stresses and how ecosystems respond.

That's why NASA is preparing to fly an advanced hyperspectral imager, as well as the next generation of Landsat, first Earth Observing System satellite, and a vegetation canopy lidar to provide the necessary data.

The answers should allow the nation to improve the management of natural resources, increase efficiency of food production, and improve marine commerce and contribute to sustainable development on Earth.

Next -- How is the chemical composition of the atmosphere changing?

We have made tremendous strides in understanding the concentrations and distributions of ozone and ozone-depleting chemicals in the stratosphere.

Now we need to validate that the new substitutes for the banned chloroflorocarbons (CFCs) have no adverse impacts themselves. We need to develop a like understanding of ozone in the troposphere . . . where it has markedly different consequences for human activity.

We're developing the first instruments capable of mapping the chemical composition of the troposphere globally, and to measure aerosol distribution and optical depth.

We need to have this knowledge of both the stratosphere and the troposphere to inform the environmental policy makers so they can arrive at decisions that minimize impacts on agricultural and industrial activities.

With sound scientific understanding , we can contribute to a healthy economy as we adjust human activities to minimize atmospheric impacts.

Last question -- Can we improve our understanding of the processes and dynamics of the Earth's surface and interior, and use this knowledge to prepare for and respond to natural hazards such as volcanoes and earthquakes?

Practical earthquake prediction may not be possible in the near term, but reliable risk characterizations are possible for the key, vulnerable regions of the globe.

The same holds true for volcanic activity. The knowledge we develop in improving our preparedness for these catastrophic events also provides hope in the future for a predictive capability.

As a first step, we are flying a topographical mapping radar in 1999 to provide a baseline digital elevation model of most of the Earth's surface, and are working with industry on a concept for an operational synthetic aperture radar (SAR) capability.

We need to engage industry in helping us answer these science questions, both as providers of science data and producers of high value information products from government satellites.

The clear message from the Administration and Congress is that we need to identify specific science goals, and target our investments in observing systems and research to meet them. And we need to apply this knowledge toward solving practical societal problems.

The National Academy of Sciences is working to document the priority questions. The Federal government research establishment, in the form of the US Global Change Research Program, is struggling to position itself to respond.

NASA is in the midst of an intensive effort to define what questions we are prepared to take on, and what missions, campaigns and research activities are required to address them. Look for a strategic research plan from us this Spring that will spell these out.

But we can't do it alone. Help us to formulate the right questions and the proper priorities. We look forward to hearing what you have to say. We want your feedback . . . more important . . . we need it.

And as we work together, there is one other thing we must do: assure our scientific results and technological innovations find their way into the hands of commercial and public sector users.

NASA's role is as an enabler; we provide technology and scientific leadership.

Industry is a partner, especially the producers of "value-added" information products that make Earth observations useful to decision-makers.

And academia plays a key role, both in expanding our scientific understanding, and in working with regional governments and businesses to design new uses for remote sensing data.

Government . . . industry . . . and academia -- when it works right it's a virtuous triangle.

When it works right, remote sensing technologies will support a robust U.S. remote sensing industry, and help apply remote sensing observations for the public good.

Advancing Earth Observing Technology

Obviously, Answering the science questions will not be easy. The task is made more challenging still by the requirement to do more with less.

In the space business, the key to doing more with less is the aggressive pursuit of advanced technology and the application of performance and cost effective system architectures.

That is why it has been my goal since I came to NASA to bring the "faster/better/cheaper" philosophy to Earth Science missions. Thanks to the very talented and very dedicated NASA team, we are making progress.

The original Earth Observing System concept was to acquire 15 years of data by launching three series of two enormous, multi-instrument spacecraft. These, what I like to call, 'Battlestar Galactica' satellites needed Titan 4-class launch vehicles to get off the ground and into orbit. The cost from program start in 1991 through 2000 was to be $17 billion.

$17 billion . . . and it's not clear that even with more money this approach could have been accomplished.

This approach had other fundamental flaws.

First, the 7 or 8 year development cycle was greater than the planned operating mission lifetime! The next mission had to be under development before the first mission was launched. There was no time for learning.

The consequence was tragic.

The science was frozen and the circle of participating scientists was closed.

Technology was also frozen; it counted on the replication of satellite and instrument sets over a 15 year period.

Can you imaging being constrained to work today with the computing power available to you 10-15 years ago?

That's effectively what we were asking the scientific community to do by freezing the design of EOS instruments to the 1988 selections. Loss of a critical instrument would have called for replacing the entire multi-billion dollar satellite, thus jeopardizing the fundamental data continuity requirement it was supposed to fulfill.

This original EOS concept was, in fact, an operational system in a research and development agency. The mismatch between the program concept and the Agency's nature and talents became grossly apparent . . . especially, as we continued with technology developments outside the EOS program.

Finally, the original EOS concept made for a poor overall risk management strategy . . . too many instruments on too few platforms. Platform co-location was chosen to achieve simultaneity of measurements, but that requirement can be met with formation flying at a much lower risk.

Even at NASA, we realized that it didn't take a rocket scientist to move away from that concept .

I am happy to report that the EOS 1st series and associated missions now comprises some 25 missions between now and 2002, on medium, medium-light, and small ELVs. Costs are lower by almost a factor of 3 for more comprehensive measurements in the same scheduled time period.

We will continue this trend in planning for our future missions. We intend to drastically shrink the size, cost and development time for missions in the next decade, but never compromise on capabilities of these systems.

Here's how:

First, we are planning future missions with a much sharper science focus; a focus on addressing a specific science question or questions rather than conducing broad surveys.

Second, we are moving toward the use of commercial satellite buses rather than developing new ones for each mission.

We have put in place a "catalog" procurement process where we can get a pre-qualified spacecraft with priced options on contract in 30 days for delivery in 2-3 years. (This used to take at least a year to negotiate, and on the average, 7 years to implement.)

Third, we have changed satellite program paradigms from science=>mission=>technology . . . to science=>technology=>mission.

In other words, we invest in technology off line and select a mission only when the technology is ready.

Fourth, we are focusing our advanced technology development efforts on scientific instruments.

We just selected 27 proposals for our Instrument Incubator program to mature instrument concepts from idea to prototype to support our future Earth Science missions.

And finally, we have begun a new series of Earth System Science Pathfinder missions, which are Principal Investigator-led, and required less than 36 months from selection to launch.

The "PI-mode" of mission management allows the scientist full authority and accountability for the success of the mission, and puts NASA in the role of assisting -- rather than directing. The PI picks the science question to be answered, the measurement approach to take, and has end-to-end mission management responsibility and authority.

We feel these are important steps . . .but, by no means are we going to stop with just smaller, cheaper versions of today's science satellites. Nor are we going to confine ourselves to low Earth orbit.

The state of the art in instrument and spacecraft technologies points to a day not too far off when sets of thousand kilogram, cubic meter satellites are replaced by constellations of micro and nano-satellites with instruments on chips that can meet a number of observational needs.

These will be stationed in a variety of orbits. They will give us synoptic views and temporal resolutions impossible today.

And these won't be independent satellites -- they will be intelligent constellations that work together to provide the views that provide the temporal and spatial resolutions users want.

They will be capable of on-board data processing and direct downlink of information to users' desktop computers in near real time, at the cost of long distance telephone calls. This will eliminate the bottlenecks caused by massive information systems on the ground.

To go with these advanced satellites, we need advanced information system architectures to ensure the accessibility and utility of the resultant data products.

Currently a user requires a high level of sophistication to navigate the current collection of data holdings to get the desired scene or data set.

The Vice President's vision of a Digital Earth is the direction we need to head, where data sets from multiple spacecraft are logically, relationally organized, and can be searched, accessed, and visualized by the phenomena or geographic areas of interest.

Make no mistake -- NASA is still committed to supplying the long term data sets we promised in the EOS program . . . but we will do it with ever more advanced satellite systems.

We will use New Millennium Program space-based technology demonstrations and other means to retire the risks associated with new technologies . . . technologies that enable advanced research and operational missions.

We aren't doing this just because we are technology enthusiasts (we are!), but because we can no longer afford to do business the old way. The old way will never allow us to answer the target set of important science questions when the answers are needed. This way lies success . . . this way lies the future.

Assuring the Health of Operational Observing Systems

We are very confident in the work we will do . . . but again, NASA isn't going answer the world's call for Earth science by itself. Domestic, commercial and international partnerships are essential.

Our role is to push the leading edge of remote sensing science and technology . We have an important but limited role in getting the benefits of new Earth science understanding into the hands of those who can make practical use of it. We are at the beginning of that chain.

The next link in the chain is the operational satellite systems; those that can be counted on over the long term by weather forecasters . . . disaster planning and response agencies . . . and scientists studying decadal and centennial climate change

Every major instrument in the current suite of NOAA weather satellites came from the predecessors of NASA' Earth Science Enterprise. But sadly, over the past decade, the technology transfer process between the two agencies has lapsed.

That linkage must be restored.

The nation has made a great step forward in moving to integrate the civilian and military operational weather satellite systems. And that program in turn has taken important steps toward embracing climate science requirements.

We are working very closely with NOAA and DOD to see the converged satellite system fly —

- an advanced Earth surface imager
- an atmospheric temperature and humidity sounding package
- an ozone column profile monitor
- and a total solar irradiance monitor.

But fundamental steps still need to be taken to ensure the future operational systems will not be the weak link in the chain that leads to broad societal benefits from Earth science.

The Nation's current vision for operational Earth observing systems is OK as far as it goes . . . but it needs to be broadened considerably.

We need to work out a larger architecture that encompasses more than 2-5 day weather & climate forecasts. It should consider Geostationary Earth Orbiters (GEO) as well as polar orbiters. It should also consider including Earth observing satellites at the solar L1 & L2 libration points in addition to other non-conventional orbits such as highly elliptical orbits that could yield constant polar coverage.

It should extend to ecosystems and oceans and polar regions. It should be responsive in real time to natural disasters, allowing national and regional authorities to zoom in on affected areas and rapidly provide that perspective to emergency response teams.

It should include an active program of advanced technology development, demonstration and infusion to enable cost and risk reduction through formations and then constellations of smaller satellites.

Rest assured . . . NASA will do its part to make this happen. As a research and development agency with a $1.4 billion annual investment in Earth Science, we will develop instrument and spacecraft technologies to make the measurements possible, and to mitigate risks to reduce the cost of operational systems.

We are investing over $250 million per year in research, data analysis and modeling, and an equal amount in data and information systems to enable scientific explorations and discovery.

Using these resources, we can help ensure proper calibration across successively more advanced instruments. And we will fund research to use the data such systems produce.

We can produce satellites and satellite constellations to meet the operational requirements of mission agencies, as we do today on a reimbursable basis for NOAA.

NASA is committed to developing and demonstrating quasi-operational data analysis systems to take full advantage of our observational capabilities. And we would like to see these capabilities make their way into the operational systems of our sister agencies.

Defining and implementing such an architecture is a long term endeavor. What can we do now to get started?

I propose three steps:

First, we need a national commitment to long-term, multi-decadal climate monitoring.

NASA will meet its 15 year EOS developmental and pre-operational monitoring commitments. But right now, no agency has a multi-decadal operational charter. Scientists plead, cajole and argue for long term, calibrated data, but we need a community and government-wide commitment to provide them.

Second, the existing operational satellite system must open itself to advanced instrument and spacecraft technology.

The current weather satellites are using 1970’s technology.

Unless we are careful, the first NPOESS satellite in 2008 will emerge in the tradition of the original, mammoth EOS satellites we abandoned in 1991--a huge, multi-instrument satellite with a ten year development cycle. And we could be locked into three decades without significant change.

We can’t let ourselves go that way.

NASA will step up to being the technology supplier, but there must be a commitment and a process to infuse new technologies into the operational systems. Otherwise, they will never be able to produce more than they are producing today.

Third, it has become clear that the nation and the world needs an operational ocean observing system to pair with the atmospheric one now extant.

NASA has proven the value and achievability of ocean topography, ocean color, ocean surface wind, and all-weather sea surface temperature measurements. The nation must have a plan to supply these and the corresponding in situ measurements on an operational basis.

The next link in the chain after operational observing system is the commercial remote sensing industry.

These are the people who will extend the results of scientific research to the broader economy. The commercial remote sensing industry comes in two major categories, both of which must be healthy for society to receive the maximum benefit of Earth Science.

The first group is the commercial providers of satellite systems.

Commercial satellite companies could be major providers in the operational architecture we put in place.

This will help us amortize the cost across a wider base to reduce the burden on taxpayers; international partnerships will also help reduce the cost to the public. We are working with the commercial community to demonstrate technology and validate data from new instruments in order to facilitate their participation.

The other important commercial category is the "value-added" information product industry, which takes data from government and other satellite systems and transforms it into information products meaningful to end users.

We work with this community to ensure unrestricted access to taxpayer-funded data and on research on applications of data to regional and local needs.

A robust commercial remote sensing industry is essential the Nation’s effort to address environmental challenges with relevant Earth Science information.

Conclusion

Earth science is truly science in the national interest.

NASA is excited to be in this business, and is committed to its success. NASA’s approach is to invest in a balanced way in observations, research and data analysis, information systems, and advanced satellite technologies to ensure the Nation has the tools to answer scientific questions about the Earth, and to put these answers to work for the benefit of society.

What started as a handy view from space grew into a vision and has become an imperative.

We as an agency will do our part. But the challenges I have outlined are challenges for the whole Earth science community. I urge you to join me in ensuring that the nation, and indeed the world, gets from us what they need, when they need it, at a price they can afford.

Because if we work together, the result will be more than an image like "Earthrise." It will be a rise in the quality of life all over the Earth.

Thank you for inviting me to join you this evening.

###